



ENVIRONMENTAL
PROTECTION
AGENCY
DALLAS, TEXAS
LIBRARY

Project Summary

Experimental Investigation of PIC Formation During the Incineration of Recovered CFC-11

JAN 6 1995

Bruce Springsteen, Loc Ho, and Greg Kryder

Experiments were conducted to investigate the formation of products of incomplete combustion (PICs) during "recovered" trichlorofluoromethane (CFC-11) incineration. Recovered CFCs have been reclaimed from previous service (e.g., from refrigerators and air conditioners) and may contain organic and inorganic (e.g., copper) contaminants. Tests involved burning the recovered CFC-11 in a propane gas flame. Combustion gas samples were taken and analyzed for volatile organic compounds as well as polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF).

Test results confirm that incineration can be used to effectively destroy recovered CFC-11; CFC-11 destruction efficiencies of greater than 99.9999 ("six nines") were consistently demonstrated for CFC-11-to-propane molar ratios of 0.06-0.6. Volatile halogenated PICs such as chloromethane, methylene chloride, dichlorodifluoromethane (CFC-12), methyl propene, chloroform, carbon tetrachloride, and tetrachloroethene, as well as non-halogenated PICs such as benzene, toluene, and acetone, were detected in the CFC-11 and propane incineration flue gas; although most of the compounds were detected at levels comparable to typical hazardous waste incinerators burning chlorinated wastes.

At the conditions studied, PCDD/PCDF were either not detected or detected at low levels (less than 10 ng/dscm @ 7% O₂ in the dry combustion gas at standard conditions) when sampling immediately downstream of the combustion flame zone, indicating no

homogeneous formation mechanisms within the flame. Additionally, low levels were detected when sampling downstream of the flue gas scrubber. However, high levels of PCDD/PCDF (217 ng/dscm @ 7% O₂) were detected downstream of the wet scrubber in a test with recovered CFC-11 that had been spiked with copper to a concentration of 300 ppm, thus demonstrating that a combination of high copper level and additional gas residence time at a temperature within the PCDD/PCDF formation window may provide conditions at which PCDD/PCDF will form. This is consistent with the results of many previous bench- and laboratory-scale studies.

A secondary goal of the study was to determine the fate of Cl and F. The results were inconclusive. Inconsistent mass balances of 29, 200, and 90% were obtained for tests burning CFCs. The ratio of chlorine (Cl) to fluorine (F) in the flue gas samples was consistent with that of the CFC-11, thus demonstrating that the Cl and F were being liberated into the flue gas at equivalent rates and indicating potential errors in the sampling methods (leaks, breakthrough of the impinger solutions, etc.) or losses within the sampling or combustor system as reasons for poor mass balances.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).



Printed on Recycled Paper

Introduction

Chlorofluorocarbons (CFCs) are implicated in the depletion of stratospheric ozone and are also contributors to global warming. As a result of the Montreal Protocol and the subsequent national policies that require phaseout of the use of CFCs and other ozone depleting substances, the destruction of considerable quantities of CFCs may be necessary to reduce current inventory levels. Incineration is the only technology available at a commercial scale for CFC destruction. However, the risks associated with CFC incineration (e.g., its combustion emissions characteristics) are not well defined.

A few full- and bench-scale studies have demonstrated that CFCs can be efficiently destroyed by incineration; however, products of incomplete combustion (PICs) (such as chlorinated hydrocarbons) may also be formed during CFC incineration. The objectives of this work are to further evaluate incineration as one of the appropriate technologies for the safe disposal of CFCs. Specifically, this study investigates the emissions of PICs and methods for their control during the incineration of "recovered" CFCs that have been in previous service (e.g., in refrigerators or automobile air conditioners). CFCs for all the previous incineration tests were unused, new commercial-grade products. Recovered CFCs may have significant contamination that may lead to formation of hazardous PICs. Recovered CFCs are likely to have had long-term contact with heat exchangers made of copper-based alloys. Copper may leach from the copper alloy tubing, particularly if acids are present. Acids may be formed as the result of CFC degradation that occurs when the CFC is exposed to overheated compressors and motors for hermetic units. This may be of critical importance since the catalytic properties of copper that lead to polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/PCDF) formation are well documented. In addition to the potential effect of copper, the effect of flue gas residence time and quenching rate on PIC formation is studied. A secondary goal is to determine the fate of fluorine (F) and chlorine (Cl) through the incineration system. Prior investigations have shown that as little as 20% of the F entering the combustion system is accounted for in the flue gas.

Experimental

The recovered trichlorofluoromethane (CFC-11) is incinerated in a Controlled Temperature Tower (CTT) combustion furnace. The furnace system is shown in Figure 1. The CTT is a down-fired furnace

with a 20-cm I.D. and an overall furnace length of 2.4 m. The reactor entry consists of a 46-cm long quarl that diverges from 5 cm at the burner to the full 20-cm I.D. The CTT is equipped with a variable swirl diffusion burner with axial air injection. With this burner, primary air is injected axially while secondary air is injected radially through swirl vanes to provide for fuel and air mixing and a stable flame. The used CFC-11 delivery system is also shown in Figure 1. CFC-11, which has a low boiling point (24°C), is delivered to the burner as a liquid to ensure that copper and other solid phase contaminants present in the CFC-11 reach the flame zone. Pressurized nitrogen is used to drive the CFC-11 to the burner located at the top of the CTT. In the burner, the CFC-11 is atomized in a spray nozzle with a mixture of propane and nitrogen. Propane, at a firing rate of 20,500 W, is provided as the primary fuel source. Combustion air is provided through the variable swirl vanes.

A summary of the target test conditions and measurements taken during each of the tests is shown in Table 1. For all tests, flame zone temperature was maintained constant at about 1,430°C, and the propane firing rate and air injection rates were held constant. Testing was conducted in two phases. Phase I consisted of evaluating the destruction efficiency (DE) and flame gas-phase formation of PICs during the incineration of recovered CFC-11 and the fate of Cl and F and consisted of four tests. Test 1 was a "system blank," involving the sole firing of propane without any CFC-11 addition, and was performed to evaluate the background flue gas species that are inherent to the fuel, system, and the sampling procedure. Tests 2-4 were performed with increasing levels of recovered CFC-11 input (0.06, 0.14, and 0.6 CFC-11-to-propane molar ratio). Tests 5-7 were performed in Phase II. Test 5, an additional system blank with propane only, was obtained because of relatively high background levels of chlorinated PICs detected in the Phase I system blank. Because Phase I results showed that the CFC-11 DE was high and that the levels of PCDD/PCDF and other PICs were low, the Phase II tests involved spiking the CFC-11 with copper, to evaluate its effect on PIC formation, primarily PCDD/PCDF. Also, samples were taken downstream of the scrubber to determine the effect of additional flue gas residence time at temperatures for chemical reactions that may form PICs.

Flue gas samples were taken for CFC-11 and other volatile halogenated and non-halogenated organic PICs using EPA SW

846 Method 0030 (Volatile Organic Sampling Train), semi-volatile PCDD/PCDF using EPA Method 23, and for Cl and F using EPA Method 26. The flue gas was also monitored continuously for oxygen (O₂), carbon dioxide (CO₂), carbon monoxide (CO), nitric oxide (NO), and total hydrocarbons (THCs), according to EPA-approved methods. Flame temperature was measured using a suction pyrometer. Propane, air, and CFC-11 injection rates were monitored using rotameters.

The flue gas sampling that was performed for each test is also shown in Table 1. For some sampling methods, sampling both upstream and downstream of the scrubber was performed, as shown in Figure 1. Method 23 samples were taken through the bottom port of the CTT, upstream of the scrubber, for all tests so that the flue gas was not exposed to any metal surfaces and thus allowing for the possible catalytic formation of PCDD/PCDF. Additionally, during Phase II, some tests were performed downstream of the scrubber to evaluate potential PCDD/PCDF formation during flue gas cooling. Method 0030 samples were taken immediately after the flue gas entered the metal exhaust ducting, upstream of the scrubber during all tests except Test 6, in which samples were taken downstream of the scrubber. Method 26 samples were taken upstream of the scrubber during Tests 1, 2, 3, and 4.

As mentioned, for Test 7, the recovered CFC-11 was spiked with a copper solution to achieve a total mixture concentration of 300 ppm copper by weight. This was done to evaluate the effects of elevated copper content in CFC-11 on the PCDD/PCDF formation.

Results

Individual test conditions, including CFC-11-to-propane injection rate, furnace firing rate, flame stoichiometry, flame temperature, and flue gas composition (O₂, CO₂, CO, THCs, and NO) are summarized in Table 2. Flame temperatures ranged from 1,340 to 1,480°C. Excellent combustion conditions were achieved for all test conditions, regardless of the CFC-to-propane ratio; i.e., <10 ppmv of THCs and <20 ppmv of CO were detected in the combustion flue gas, corrected to 7% O₂ at standard conditions.

Volatile PICs, determined from the EPA SW 846 Method 0030 sampling trains, are shown in Table 3 for all tests (given in µg/dscm @ 7% O₂). Although CFC-11 was detected at quantifiable levels in the flue gas for the tests burning CFC-11, it was detected at relatively low levels (2-20 µg/dscm). Additionally, for all tests it was

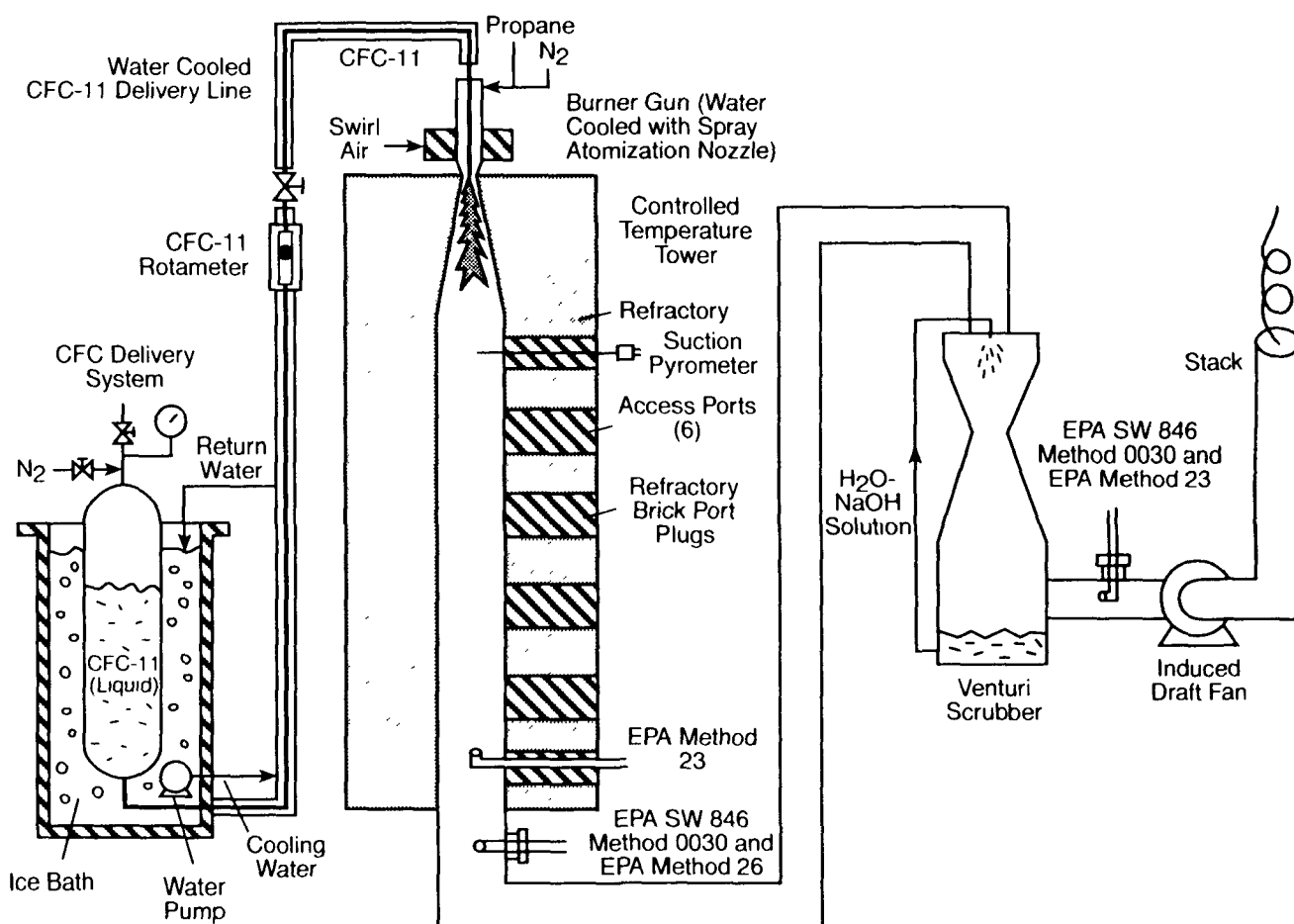


Figure 1. CFC-11 incineration system: CFC-11 delivery system, Controlled Temperature Tower, venturi scrubber/fan/stack, and critical flue gas sampling locations denoted by EPA methods.

detected at below the analytical method practical quantification level. Corresponding destruction efficiencies of CFC-11, shown in Table 4, are consistently greater than six nines.

In addition to CFC-11, other chlorinated PICs were detected, including dichlorodifluoromethane (CFC-12) (1-15 $\mu\text{g/dscm}$), carbon tetrachloride (2-120 $\mu\text{g/dscm}$), chloromethane (0-12,300 $\mu\text{g/dscm}$), methylpropene (3-20 $\mu\text{g/dscm}$), methylene chloride (30-140 $\mu\text{g/dscm}$), and chloroform (3-70 $\mu\text{g/dscm}$). Non-chlorinated PICs were also detected, including benzene (2-14 $\mu\text{g/dscm}$), toluene (11-460 $\mu\text{g/dscm}$), and acetone (5-85 $\mu\text{g/dscm}$). There was no apparent influence of PIC formation from the CFC-11-to-propane ratio at the conditions studied (0.06-0.6 molar ratio), and no apparent effect of recovered CFC as opposed to new pure commercial grade as used in previous studies. Note that these volatile PIC levels are similar to levels from typical hazardous waste incinerators burning chlorinated wastes.

PCDD/PCDF flue gas levels (shown in ng/dscm @ 7% O_2) are given in Table 5. PCDD/PCDF were not detected in Test 1 (system blank), indicating no background contamination in the propane combustion gas, sampling train, recovery reagents, or resulting from the analytical procedure. PCDD/PCDF were not detected in Tests 3 and 4 (0.14 and 0.6 CFC-11-to-propane molar ratio, respectively) with sampling at the CTT outlet, indicating no homogeneous gas-phase formation of PCDD/PCDF during CFC-11 combustion at the baseline furnace conditions. Low levels of OCDD and OCDF were detected in Test 2 (0.06 CFC-11-to-propane molar ratio). The presence of copper in the recovered CFC-11 had little or no effect on PCDD/PCDF formation at the conditions of these tests. Note the low level of copper (0.2 ppm) in the recovered CFC-11.

Test 6 results upstream of the scrubber showed again that PCDD/PCDF were not formed at significant levels in the flame region, while downstream scrubber sam-

pling results indicated that additional gas residence time and exposure to the metal-lined flue gas duct did not promote PCDD/PCDF formation. Test 7 was conducted with CFC-11 that was spiked with copper to a concentration of 300 ppm by weight, increased from its original 0.2 ppm. Low levels from sampling results upstream of the scrubber indicated that the presence of increased levels of copper in the CFC did not promote high temperature gas-phase PCDD/PCDF formation. However, high levels of PCDD/PCDF (217 ng/dscm @ 7% O_2) were detected in the sampling train located downstream of the scrubber. The combination of high levels of copper with additional gas residence time and exposure to metal flue gas duct surface in a temperature range that is conducive to PCDD/PCDF formation provided conditions at which PCDD/PCDF may form. The flue gas entering the scrubber was at a temperature of about 370°C, which is within the PCDD/PCDF formation "temperature window" of from 200 to 450°C. This con-

Table 1. Test Conditions and Sampling Schedule

Phase	Test No.	Test Conditions		Flue Gas Sampling Schedule				
		CFC-11-to-Propane Molar Ratio	CFC Copper Spiking	Method 23 (PCDD/PCDF)		Method 0030 (PICs)		Method 26 (Cl/F)
				U ^a	D ^b	U	D	U
I	1	0	na ^c	x ^d	np ^e	x	np	x
	2	0.05	no	x	np	x	np	x
	3	0.15	no	x	np	x	np	x
	4	0.6	no	x	np	x	np	x
II	5	0	na	np	np	x	np	np
	6	0.15	no	x	x	np	x	np
	7	0.15	yes ^f	x	x	x	np	np

^aSampling upstream of wet scrubber.

^bSampling downstream of wet scrubber.

^cna - not applicable for tests without CFC.

^dx - sampling performed at this location and condition.

^enp - sampling not performed at this location.

^fSpiked with 300 ppm of copper by weight.

Table 2. Summary of Test Conditions^a

Test No.	CFC-11-to-Propane Molar Ratio ^b	Flame Temperature (°C)	Flue Gas Composition				
			O ₂ (vol. %)	CO ₂ (vol. %)	CO ^c (ppmv)	THC ^c (ppmv)	NO ^c (ppmv)
1	0	1,480	8.8	5.3	17	2	68
2	0.06	1,430	8.8	6.5	17	6	52
3	0.14	1,370	7.4	8.5	19	8	58
4	0.6	1,340	7.2	8.3	20	10	39
5	0	1,480	6	10.0	21	2	86
6	0.14	1,430	7.4	8.5	19	8	58
7	0.14 ^d	1,430	7.4	8.5	19	8	58

^a For all tests, propane firing rate = 20,510 W, and mass-based SR = 1.38.

^b (Moles CFC-11)/(Mole propane).

^c@ 7% O₂ in dry gas at standard conditions.

^dCFC-11 spiked with 300 ppm of copper by weight.

clusion is consistent with other research that has shown that residence time in the post-combustion cooling zone was the primary factor in PCDD/PCDF formation. Note that the PCDD/PCDF may have formed within the wet scrubber; tests immediately upstream of the scrubber would need to be performed to determine the exact formation mechanisms.

Table 6 summarized the results of the EPA Method 26 Cl/F testing. Mass balances (i.e., comparison of the Method 26 sampling train results with those predicted

from the CFC-11 composition and input rate) were not consistent. For Test 2 (0.06 CFC-11-to-propane molar ratio), the mass balance is very low for both Cl and F (about 20%); for Test 3, the mass balance is high (200%); while for Test 4, the mass balance is good (80 and 100% for Cl and F, respectively). The weight ratios of Cl to F detected in the Method 26 samples agree well with the theoretical level based on the composition of CFC-11. Thus, both F and Cl are liberated into the flue gas at the same rate. Detection of the expected

ratios of Cl and F in each of the Method 26 trains is an indication that the analytical results are reliable. Thus, the poor mass balances for Tests 2 and 3 may be a result of sampling train leakage, incorrect monitoring of sample train flue gas sampling rates, or losses with the combustor or sampling train systems.

Note that, due to the high levels of acid gases (HCl and HF) generated during the combustion of CFCs, all PCDD/PCDF and volatile PIC flue gas sampling at a location upstream of the scrubber required

Table 3. Summary of Volatile PIC Flue Gas Concentrations

VOC Species	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
Dichlorodifluoromethane ^a	8.0	1.9	14.9	1.3	< 0.5	10.0	1.2
Chloromethane	45.9	1213.0	1030.3	12308.4	< 0.5	47.3	< 0.5
2-Methylpropene	3.2	5.3	4.1	6.1	0.7	22.8	6.5
Vinyl Chloride	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Bromomethane	2.5	5.1	2.8	8.4	< 0.5	4.9	0.6
Chloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Trichlorofluoromethane ^b	2.3	2.0	2.1	2.8	< 0.5	19.2	5.5
1,1-Dichloroethene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Carbon Disulfide	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	7.0	4.0
Iodomethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Acetone	39.2	84.3	10.0	4.7	3.0	79.4	36.9
Methylene Chloride	142.5	142.8	124.9	145.4	0.2	144.5	38.1
Vinyl Acetate	22.2	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
trans-1,2-Dichloroethene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
2-Methyl-2-Propanol	< 0.6	< 0.6	< 0.5	< 0.5	0.7	4.9	< 0.5
Hexane	0.4	2.5	4.0	< 0.5	0.2	4.9	< 0.5
1,1-Dichloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
2-Butanone	0.6	0.5	0.5	< 0.5	< 0.5	10.3	3.6
Chloroform	0.2	18.0	20.2	24.0	< 0.5	70.6	3.2
1,1,1-Trichloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	5.7	< 0.5
Carbon Tetrachloride	69.0	117.4	38.0	57.4	< 0.5	95.7	2.5
Benzene	3.4	1.8	1.7	14.6	0.5	9.0	10.3
1,2-Dichloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Fluorobenzene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
2,5-Dimethyl-3-Hexene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
2-Chloro-2-Methylpropane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Heptane	< 0.6	0.5	0.2	< 0.5	< 0.5	4.9	< 0.5
Trichloroethene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,2-Dichloropropane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,4-Dioxane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Bromodichloromethane	< 0.6	0.4	< 0.5	3.8	< 0.5	4.9	< 0.5
cis-1-3-Dichloropropene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
4-Methyl-2-Pentanone	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Toluene	377.2	459.3	209.8	157.8	0.5	17.6	11.7
trans-1,3-Dichloropropene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,1,2-Trichloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	6.5	< 0.5
Tetrachloroethene	< 0.6	0.3	< 0.5	0.5	< 0.5	25.4	5.6
2-Hexanone	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Dibromochloromethane	< 0.6	< 0.6	< 0.5	1.5	< 0.5	4.9	< 0.5
Chlorobenzene	< 0.6	0.5	0.5	0.8	< 0.5	4.9	0.4
Ethyl Benzene	< 0.6	< 0.6	< 0.5	< 0.5	0.2	4.9	< 0.5
m,p-Xylene	0.3	< 0.6	< 0.5	0.5	0.6	4.9	0.6
Nonane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	9.6	0.5
O-Xylene	< 0.6	< 0.6	< 0.5	< 0.5	0.2	4.9	< 0.5
Styrene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	3.5	9.5
Bromoform	< 0.6	< 0.6	< 0.5	0.8	< 0.5	16.9	< 0.5
Cumene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	12.8	< 0.5
1,2,3-Trichloropropane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,1,2,2-Tetrachloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,4-Dichloro-2-Butene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
Pentachloroethane	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,3-Dichlorobenzene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5
1,4-Dichlorobenzene	< 0.6	< 0.6	< 0.5	< 0.5	< 0.5	4.9	< 0.5

Concentrations reported in µg/dscm @ 7% O₂ at standard conditions.

< - Concentrations below method detection limit; detection limit used.

^aCFC-12.

^bCFC-11.

modification of standard sampling and analytical procedures. However, these modifications are not believed to affect the conclusions of the study; all quality assurance and quality control issues for this project were met. Further discussion of these issues is contained in the Quality Control Evaluation in the full report.

Conclusions

Test results further confirm that incineration can be used to effectively destroy recovered CFC-11; CFC-11 destruction efficiencies of greater than 99.9999 ("six nines") were consistently demonstrated for CFC-11-to-propane fuel molar ratios of 0.06-0.6. Volatile halogenated PICs (e.g., chloromethane, methylene chloride, CFC-

12, methyl propene, chloroform, carbon tetrachloride, and tetrachloroethene) as well as non-halogenated PICs (e.g., benzene, toluene, and acetone) were detected in the CFC-11 and propane combustion flue gas; although most of the compounds were detected at levels comparable to hazardous waste incinerators burning chlorinated wastes.

At the conditions evaluated, PCDD/PCDF were either not detected or detected at low levels (<10 ng/dscm @ 7% O₂) when sampling immediately downstream of the combustion flame zone, indicating no homogeneous formation mechanisms within the flame. Additionally, low levels were detected when sampling downstream of the flue gas scrub-

ber. However, high levels of PCDD/PCDF (217 ng/dscm @ 7% O₂) were detected in a test downstream of the wet scrubber with recovered CFC-11 that had been spiked with copper to a concentration of 300 ppm, demonstrating that a combination of high copper and additional gas residence time at a temperature within the PCDD/PCDF formation window provided conditions at which PCDD/PCDF formed. This is consistent with the results of other bench- and laboratory-scale studies.

Tests to determine the fate of Cl and F during incineration were inconclusive due to possible sampling problems or losses with the combustor or sampling systems due to the very high levels of acids (thousands of parts per million) in the flue gas.

Table 4. CFC-11 Destruction Efficiencies

Test No.	CFC-11-to-Propane Molar Ratio	CFC-11 Destruction Efficiency (%)	Emission Ratio (ng CFC-11 in Flue Gas to g CFC-11 input)
2	0.06	99.99998	230
3	0.14	99.99999	121
4	0.6	99.99999	35
6	0.14	99.99990	1076
7	0.14	99.99997	307

Table 5. Summary of PCDD/PCDF Flue Gas Concentrations

Congener	Flue Gas Concentration (ng/dscm @ 7% O ₂)							
	Test 1	Test 2	Test 3	Test 4	Test 6		Test 7	
	CTT ^a	CTT	CTT	CTT	CTT	Scrub. ^b	CTT	Scrub.
PCDD								
TCDD	nd ^c	nd	nd	nd	nd	nd	nd	nd
PeCDD	nd	nd	nd	nd	nd	nd	nd	nd
HxCDD	nd	nd	nd	nd	nd	nd	nd	5.3
HpCDD	nd	nd	nd	nd	2.7	nd	nd	11.5
OCDD	nd	5.5	nd	nd	nd	nd	nd	13.3
Total PCDD	nd	5.5	nd	nd	2.7	nd	nd	30.1
PCDF								
TCDF	nd	nd	nd	nd	nd	nd	nd	50.5
PeCDF	nd	nd	nd	nd	nd	nd	3.2	66.6
HxCDF	nd	nd	nd	nd	1.6	nd	nd	41.6
HpCDF	nd	nd	nd	nd	nd	nd	nd	10.8
OCDF	nd	2.1	nd	nd	nd	nd	nd	17.9
Total PCDF	nd	2.1	nd	nd	1.6	nd	3.2	187.4
Total PCDD/PCDF	nd	7.6	nd	nd	4.3	nd	3.2	217.5

^aSampling at outlet of CTT.

^bSampling downstream of wet scrubber.

^cnd - Not detected in sample (below Method Detection Limit).

Table 6. Fate of Chlorine and Fluorine

Test No.	CFC-11-to-Propane Molar Ratio	Output in Flue Gas (Method 26)		Input to Furnace (CFC-11 Feedrate)		Input/Output Ratio		Cl/F Ratio	
		Cl (g/hr)	F (g/hr)	Cl (g/hr)	F (g/hr)	Cl (%)	F (%)	Method 26 (%)	CFC-11 (%)
1	0	<1	<1	0	0	na ^a	na	na	na
2	0.06	43	8	205	38	21	22	515	537
3	0.14	909	199	464	86	196	231	456	537
4	0.6	1721	405	2210	411	78	98	425	537

^ana - Not appropriate for propane-only firing.

Bruce Springsteen, Loc Ho, and Greg Kryder are with Energy and Environmental Research Corp., Santa Ana, CA 92705.

***C. W. Lee** is the EPA Project Officer (see below).*

The complete report, entitled "Experimental Investigation of PIC Formation During the Incineration of Recovered CFC-11," (Order No. PB94-214772; Cost:

\$36.50, subject to change) will be available only from:

National Technical Information Service

5285 Port Royal Road

Springfield, VA 22161

Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Air and Energy Engineering Research Laboratory

U.S. Environmental Protection Agency

Research Triangle Park, NC 27711

United States
Environmental Protection Agency
Center for Environmental Research Information
Cincinnati, OH 45268

BULK RATE
POSTAGE & FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use
\$300

EPA/600/SR-94/163